A Chipless RFID Unit Based on Interference for Tag Location

Nuanfeng Zhang, Xiongying Liu, Tianhai Chang

School of Electronic and Information Engineering
South China University of Technology
Guangzhou, China

Email：***liuxy@scut.edu.cn***

Copyright

©The use of this work is restricted solely for academic purposes. The author of this work owns the copyright and no reproduction in any form is permitted without written permission by the author.

APCAP 2017 Xi'an西安

華南理工大學 SOUTH CHINA UNIVERSITY OF TECHNOLOGY 1934

Good Memory With Prof. Zhang

Happy 80th Birthday!

Abstract

A chipless RFID reading unit based on electromagnetic (EM) interference is designed for tag location in the frequency domain. The proposed unit consists of a directional reader antenna, a chipless tag, and a reference metal plane. The relative distance between tag and reference plane can be determined by using the peaks/dips of the scattered radar cross section (RCS). Due to the existence of reference plane, the problems of reading range and the information collision can be relieved. From the simulation results, it shows that the accuracy of the location would be very high if the energy reflected by the tag and that scattered by reference plane, which are captured by the reader antenna, are close to each other.

Keywords: Chipless RFID tag, Interference, Localization, Radar cross section (RCS), RF identification (RFID).

Biography

XiongYing Liu is a Full Professor with the School of Electronic and Information Engineering at the South China University of Technology, Guangzhou, China. He received the Bachelor degree in instrument science & technology from the Jiling University, ChangChun, China, M.S. degree in Physical Electronics and Ph.D. degree in circuits and systems from South China University of Technology, GuangZhou, China, respectively in 1996, 2001 and 2004.

He was an Electrical Engineering with the FuShun Steel Plant, FuShun, China, in 1996, a Research Assistant with the Hong Kong Polytechnic University, Hong Kong, a Visiting Scholar with the Georgia Institute of Technology, Atlanta, GA, USA. He has authored or co-authored over 100 technical papers in refereed journals and conference proceedings. He holds 22 granted and filed Chinese patents. His current research interest includes electromagnetic engineering, antennas & propagation for body-centric communications, and RFID technology.

Dr. Liu is a Member of IEEE-APS. He was a recipient/co-recipient of the 2014 IEEE APS Symposium Honorable Mention Student Paper Contest, the 2013 National Conference on Antennas Best Paper Award.

Content

1. Introduction

2. Design of Chipless RFID Tag and System Unit

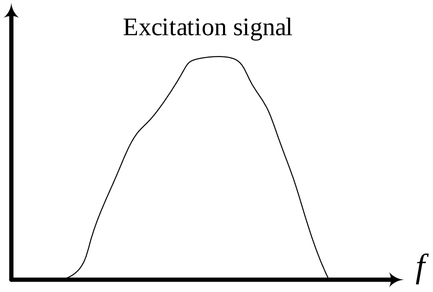
3. Theoretical Basis and Working Principle

4. Results and Analysis

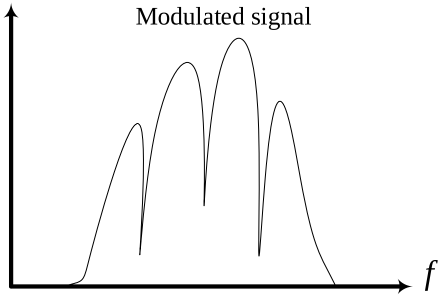
5. Conclusions

Introduction – Backscattering chipless RFID

➢ Coding Principle

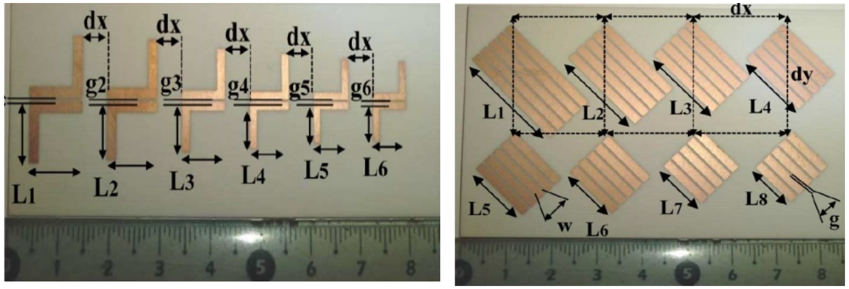


The spectrum of excitation signal



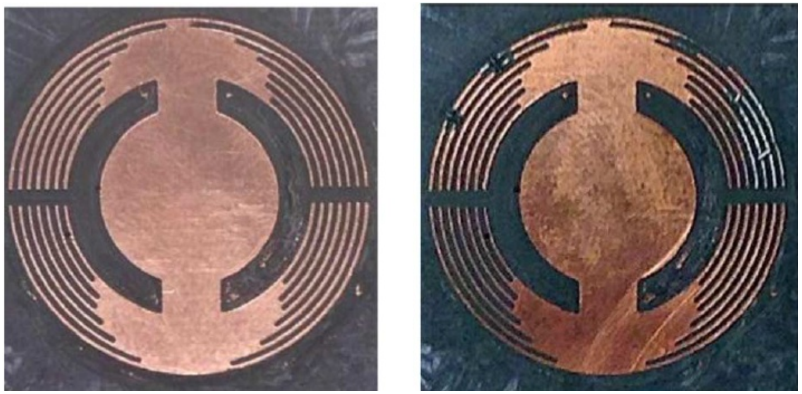
The spectrum of reflected signal

➢ Ex.1


dx
g2
g3
g4
g5
g6
L1
L2
L3
L4
L5
L6
dx
dy
L1
L2
L3
L4
L5
w
L6
L7
L8
g

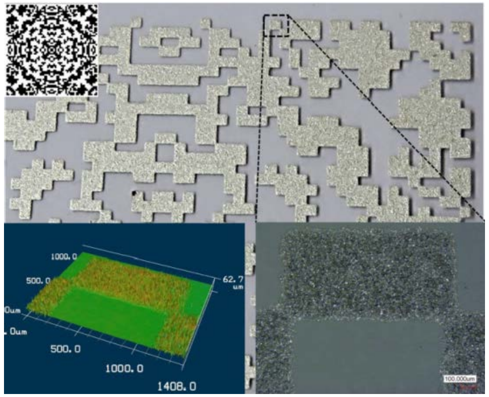
A. Vena, **E. Perret**, and S. Tedjni, "**A depolarizing chipless RFID tag for robust detection and its FCC compliant UWB reading system**," ***IEEE Trans. Microw. Theory Techn***., vol. 61, no. 8, pp. 2982–2994, Aug. 2013.

➢ Ex.2



R. Rezaiesarlak, and **M. Manteghi**, "**Complex-natural-resonance-based design of chipless RFID tag for high-density data**," ***IEEE Trans. Microw. Theory Tech***., vol. 62, no. 2, pp. 898–904, Feb. 2014.

➢ Ex.3


1000.0
500.0
62.7 um
0um
0um
500.0
1000.0
1408.0

D. Betancourt, M. Barahona, K. Haase, G.Schmidt, A. Hübler, and **F. Ellinger**, "**Design of Printed Chipless-RFID Tags With QR-Code Appearance Based on Genetic Algorithm**," ***IEEE Trans. Microw. Theory Tech***., vol. 65, no. 5, pp. 2190–2195, May 2017.

Introduction –Two location methods(1)

➢ Round Trip Time of Flight, RTOF

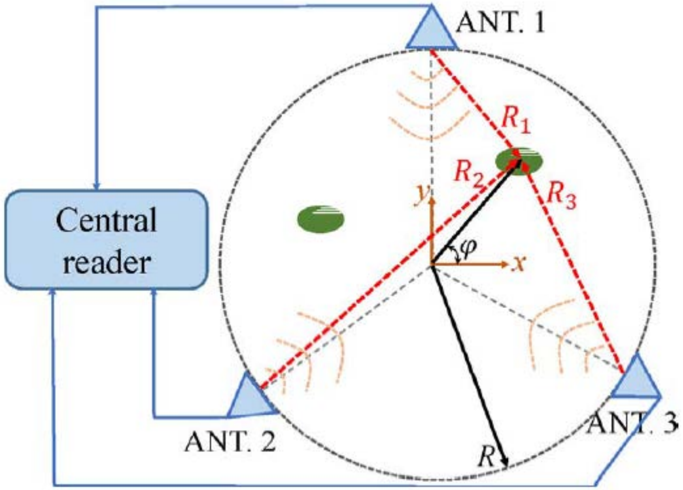

ANT. 1
R_1
R_2
R_3
y
φ
x
Central reader
ANT. 2
ANT. 3
R

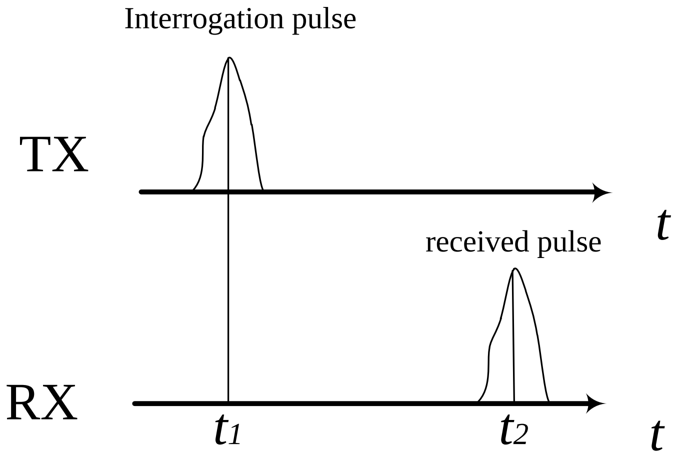
Fig. 1 Scheme for chipless tag location

R.-E. A. Azim and **N. C. Karmakar**, “**Chipless RFID tag localization**,” ***IEEE Trans. Microw. Theory Tech***., vol. 61, no. 11, pp. 4008–4017, Nov. 2013.

R. Rezaiesarlak and **M. Manteghi**, “**A space-frequency technique for chipless RFID tag localization**,” ***IEEE Trans. Antennas Propag***., vol. 62, no. 11, pp. 5790–5797, Nov. 2014.

N. Zhang, M. Hu, L. Shao and **J. Yang**, “**Localization of printed chipless RFID in 3-D space**,” ***IEEE Microwave and Wireless Components Letters***., vol. no. 5, pp. 373–375, May 2016.

➢ Working principle


Interrogation pulse
TX
t
received pulse
RX
t_1
t_2
t

$$d = \frac{t_2 - t_1}{2} \cdot c$$

Drawbacks:

✓(1)Need to record the start time

✓(2)The accuracy is depended on the shape of the pulse.

Introduction –Two location methods(2)

➢ RSS(received signal strength)

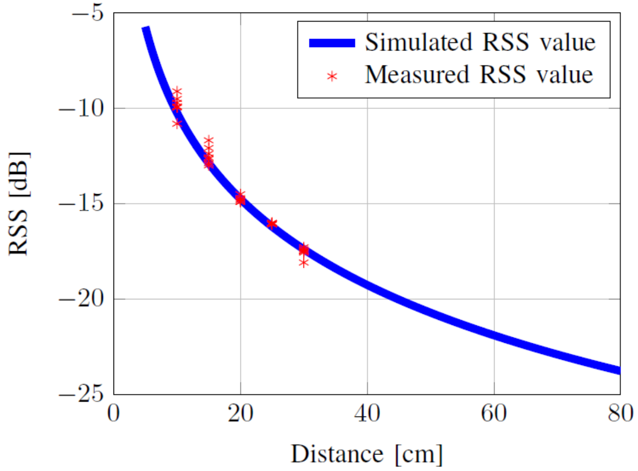


Fig. 2 Measured vs. simulated distance

A. Fawky, M. Khaliedl, A. El-Awamry, T Kaiser “**Frequency coded chipless RFID tag localization using multiple antennas**” *in EuCAP 2017 -11th European Conference on Antennas and Propagation*, pp. 1–4 Paris, France Mar. 2017.

Drawbacks:

✓With distance increasing , distance estimation is becoming inaccurate.

➢ AOA(angel of arrival)

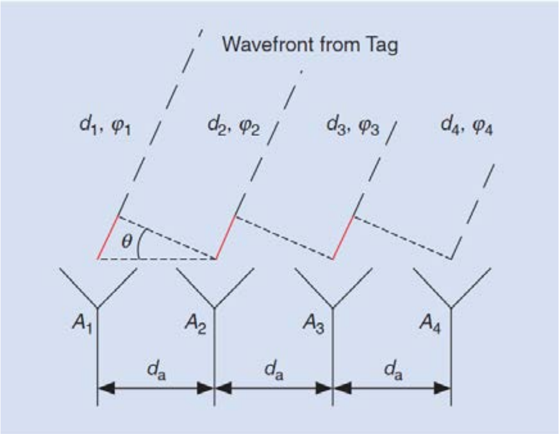

Wavefront from Tag
d_1, φ_1
d_2, φ_2
d_3, φ_3
d_4, φ_4
θ
A_1
A_2
A_3
A_4
d_a
d_a
d_a

Fig. 3 Four antennas for angle of arrival measurement

R. Miesen et al., “ **Where is the tag?**, ” *IEEE Microw. Mag*., vol. 12, no. 7, pp. S49–S63, Dec. 2011.

Drawbacks:

✓With distance decreasing , angle position estimation is becoming inaccurate.

Content

1. Introduction

2. Design of Chipless RFID Tag and System Unit

3. Theoretical Basis and Working Principle

4. Results and Analysis

5. Conclusions

Chipless RFID Tag Design

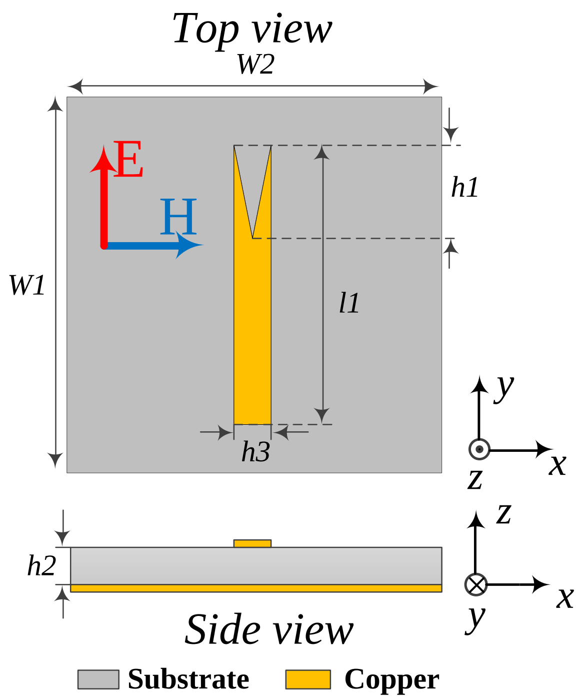

Top view
W2
E
H
W1
h1
l1
h3
y
z
x
z
h2
x
y
Side view
▨ Substrate
🟨 Copper

Fig. 4 Configuration of the tag

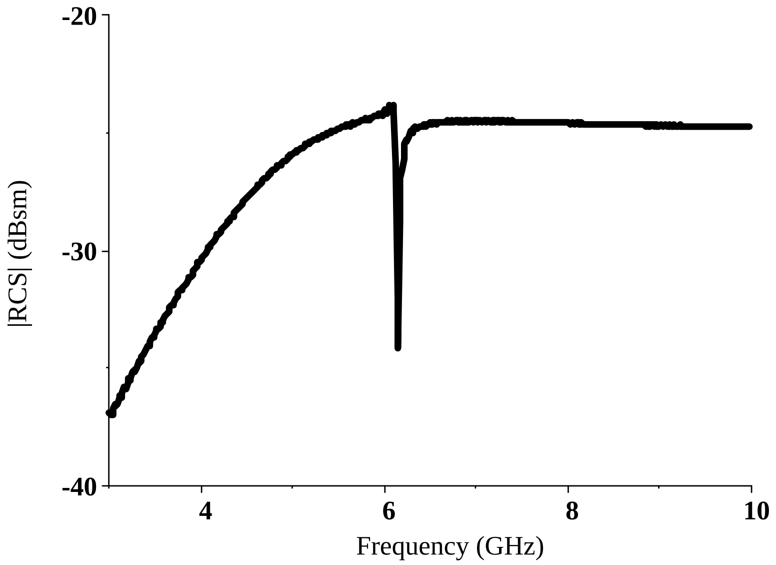


Fig. 5 RCS magnitude of the tag

Substrate: Rogers 4003C
(ε_r = 3.38, tanσ=0.0027)

Geometrical parameter

Symbol	*h1*	*h2*	*h3*	*W1=W2*	*l1*
Value (mm)	5 mm	0.635 mm	2 mm	20 mm	15 mm

System Unit Design

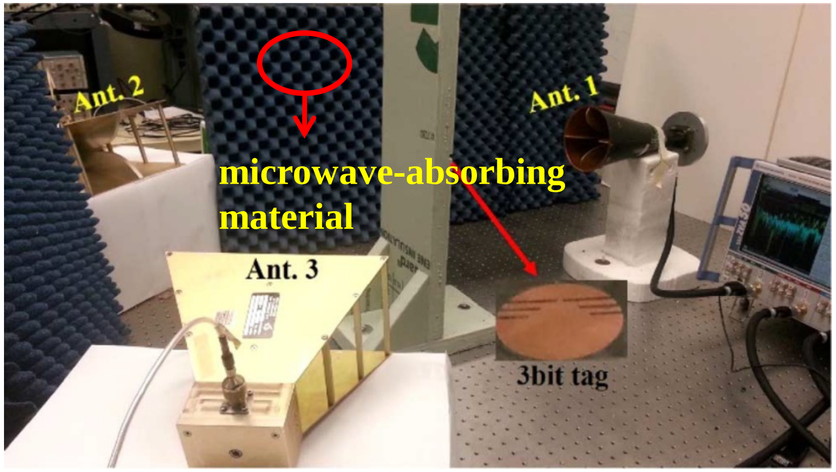

Ant. 2
Ant. 1
microwave-absorbing material
Ant. 3
3bit tag

Fig. 6 Measurement setup for localizing chipless RFID tag

R. Rezaiesarlak and **M. Manteghi**, “**A space-frequency technique for chipless RFID tag localization**,” *IEEE Trans. Antennas Propag.*, vol. 62, no. 11, pp. 5790–5797, Nov. 2014.

✓ Microwave-absorbing material is used to avoid interference from environment to improve decoding accuracy.

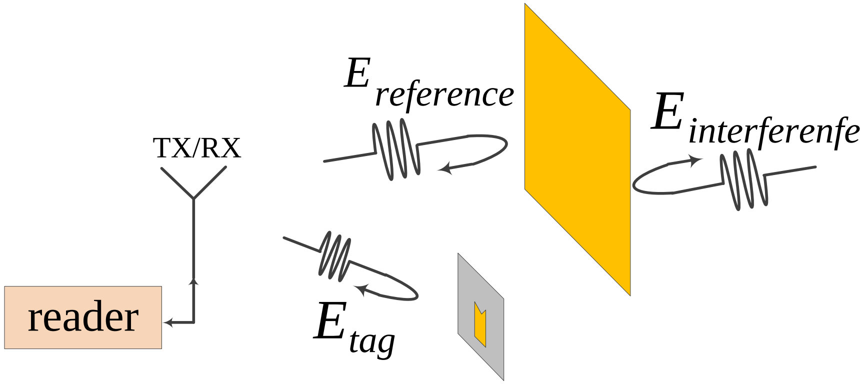

$E_{reference}$
$E_{interferenfe}$
TX/RX
reader
E_{tag}

Fig. 7 Model of proposed system

✓ Using perfect conductor to replace wave-absorbing material can get a similar effect.

✓ Distance between the tag and reference plane can be calculated in a simple way.

✓Create a relative stable environment

Content

1. Introduction

2. Design of Chipless RFID Tag and System Unit

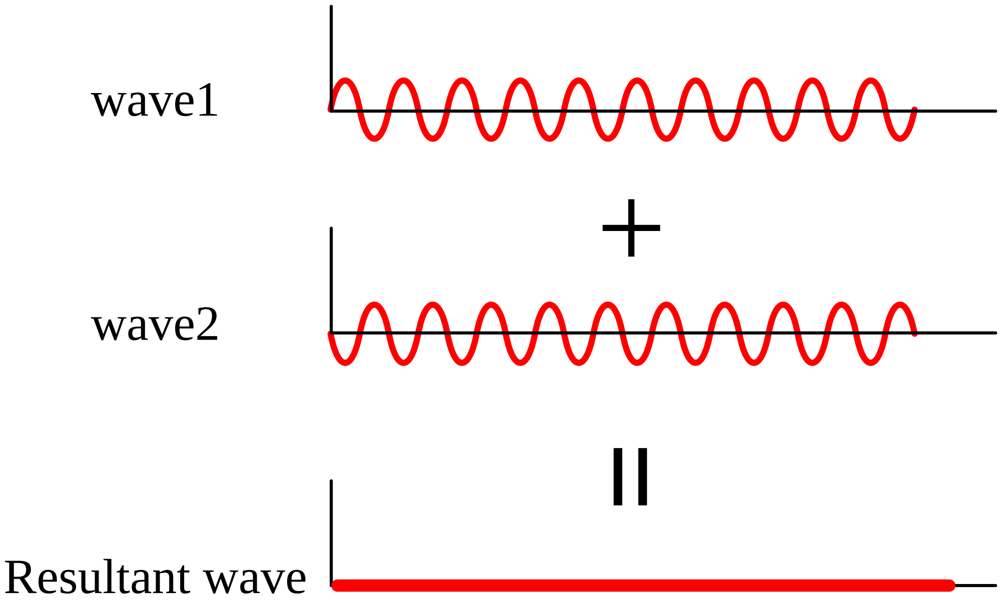
3. Theoretical Basis and Working Principle

4. Results and Analysis

5. Conclusions

Theoretical Basis and Working Principle

➢Destructive interference


wave1
+
wave2
=
Resultant wave

✓Destructive interference occurs when the phase difference is an odd multiple of π

Working Principle

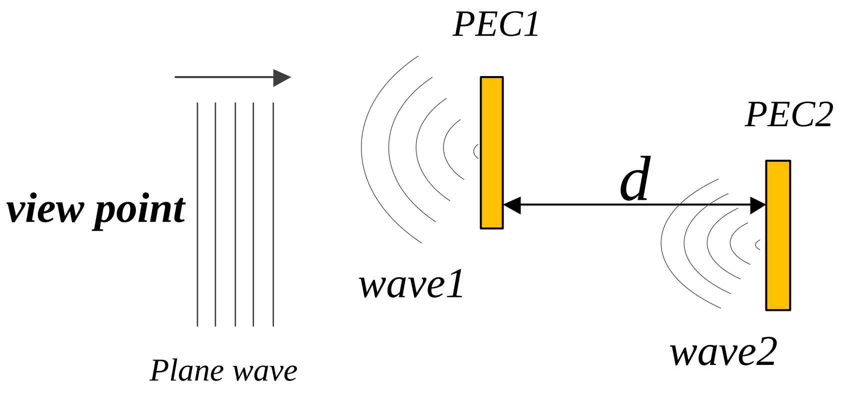


Fig. 8 Top view of configuration in simulation

Here d = 100 mm

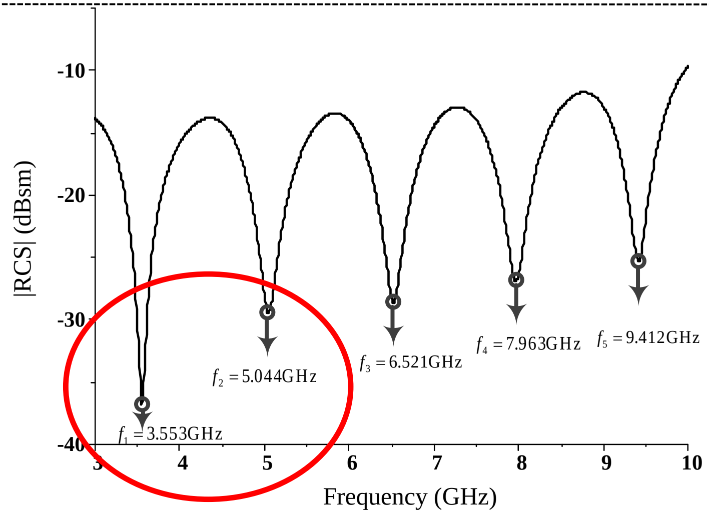


Fig. 9 RCS of the configuration

RCS trough can be summed up as the expression

$$\frac{2d}{\lambda}2\pi = 2n\pi + \pi \Leftrightarrow \frac{2d}{\lambda} = n + \frac{1}{2} \tag{1}$$

for convenience Eq. (1) can be converted into

$$\frac{2d \cdot f}{c} = n + \frac{1}{2} \tag{2}$$

f_1 and f_2 satisfy the following equations

$$\frac{2d \cdot f_1}{c} = n_1 + \frac{1}{2} \tag{3}$$

and

$$\frac{2d \cdot f_2}{c} = n_1 + 1 + \frac{1}{2} \tag{4}$$

Hence, d can be deduced as

$$d = \frac{c}{2(f_2 - f_1)} \tag{5}$$

According to data in fig. 9 the numerical distance d = 100.603 mm

Working Principle

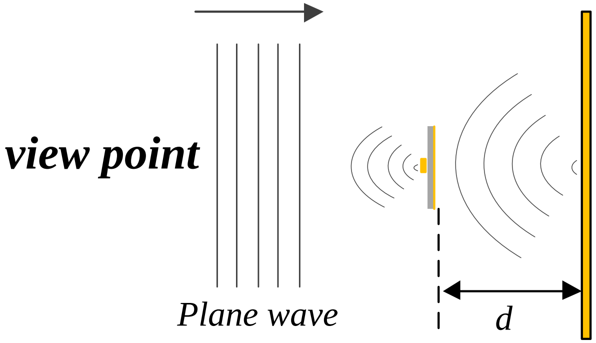


Fig. 10 Top view of proposed system in simulation

✓The area of the tag is 20 × 20 mm^2, and the area of the reference plane is 160 × 160 mm^2.

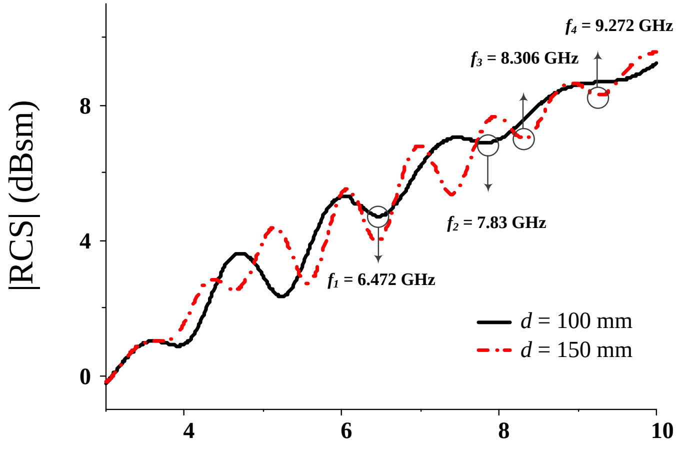


Fig. 11 RCS of proposed system

➢ Calculated result

$$d = \frac{c}{2(f_2 - f_1)} \qquad (6)$$

✓Based on equation(5)

✓When true distance is 100 mm, numerical distance is 110.45 mm.

✓when true distance is 150 mm, numerical distance is 155.2 mm.

☐Advantage :

Phase difference is determined by the distance difference.

✓ Don’t need to consider shape of pulse.

✓ Don’t need to record the start time.

Content

1. Introduction

2. Design of Chipless RFID Tag and System Unit

3. Theoretical Basis and Working Principle

4. Results and Analysis

5. Conclusions

Simulated Result

TABLE I

Simulated results with Reference plane Area of 160 × 160 mm^2

Position No.	Real Distance *d* (mm)	Computed Result (mm)	Relative Error
1	100	110.4	10.4%
2	150	155.2	3.46%
3	200	210.08	5.04%
4	250	258.2	3.28%
5	300	310.6	3.53%

TABLE II

Simulated results with Reference plane Area of 80 × 80 mm^2

Position No.	Real Distance *d* (mm)	Computed Result (mm)	Relative Error
1	100	102.04	2.4%
2	150	147.78	1.48%
3	200	196.59	1.71%
4	250	249.17	0.33%
5	300	301.81	0.6%

✓Value of relative error is small

✓With distance increasing, relative error declines

✓Compared table one with two, using reference plane with smaller reflected area can achieve higher accuracy

Measured Result

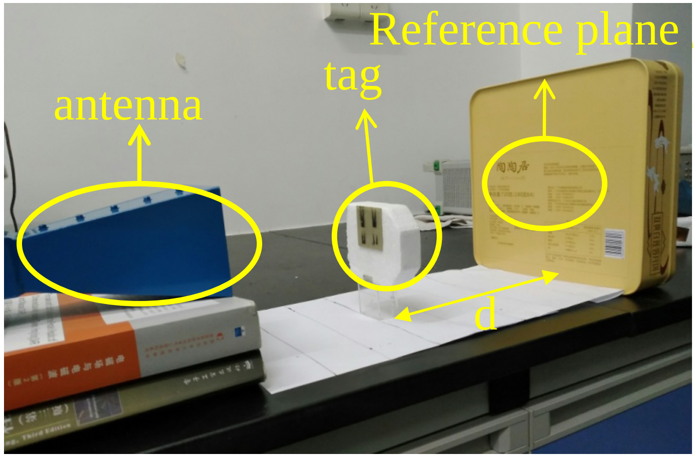
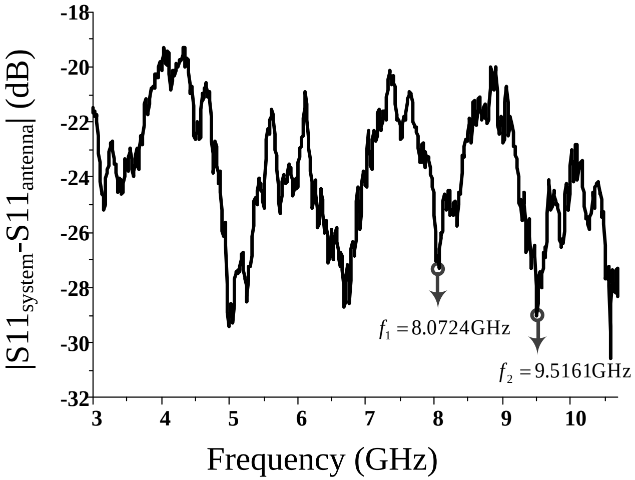
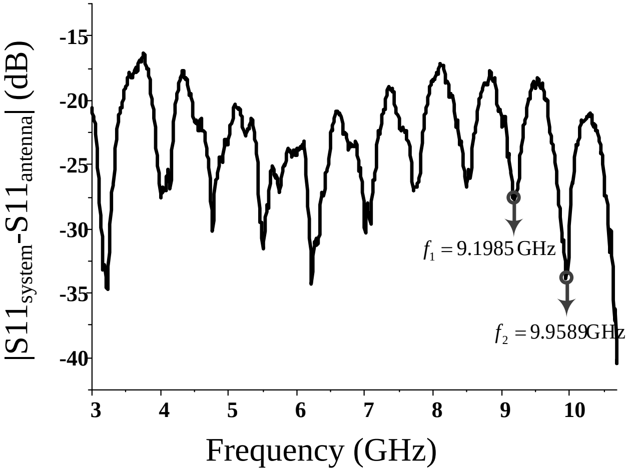


Fig. 12 Measurement setup for localizing chipless RFID tag

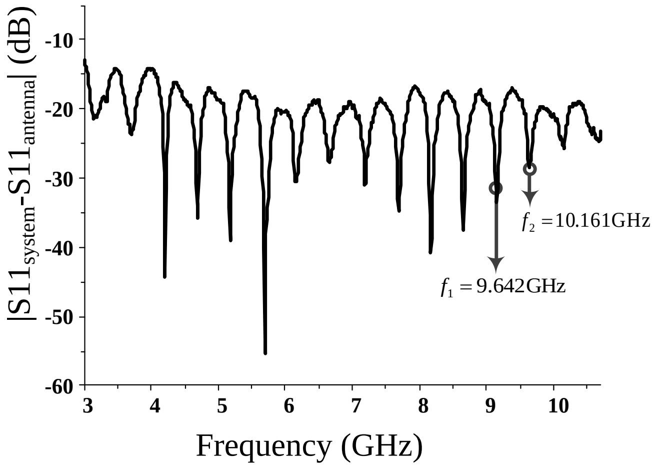
✓The area of tag is 40 × 40 mm², And the area of reference plane is 240 × 240 mm²



✓True distance d = 100 mm, numerical distance d' = 103.89 mm



✓True distance d = 200 mm, numerical distance d' = 196.28 mm



✓True distance d=300 mm, numerical distance d' = 289.01 mm

Measured Result

TABLE III

Measurement results with Reference plane Area of 240 × 240 mm^2,with tag area of 40 × 40 mm^2

Position No.	Real Distance *d* (mm)	Computed Result (mm)	Relative Error
1	100	103.89	3.89%
2	150	157.23	4.82%
3	200	196.28	1.86%
4	250	243.42	2.63%
5	300	289.01	3.66%
6	350	324.67	7.23%

TABLE IV

Measurement results with Reference plane Area of 240 × 240 mm^2,with copper plane area of 20 × 20 mm^2

Position No.	Real Distance *d* (mm)	Computed Result (mm)	Relative Error
1	150	140.39	6.41%
2	200	194.80	2.60%
3	250	246.03	1.58%
4	300	294.00	2.00%
5	350	338.98	3.14%

✓Value of relative error is small

✓Absolute errors are less than 26 mm

✓If using small reflection area tag, distance d can’t be obtained when exact distance is small.

Content

1. Introduction

2. Design of Chipless RFID Tag and System Unit

3. Theoretical basis and Working principle

4. Results and Analysis

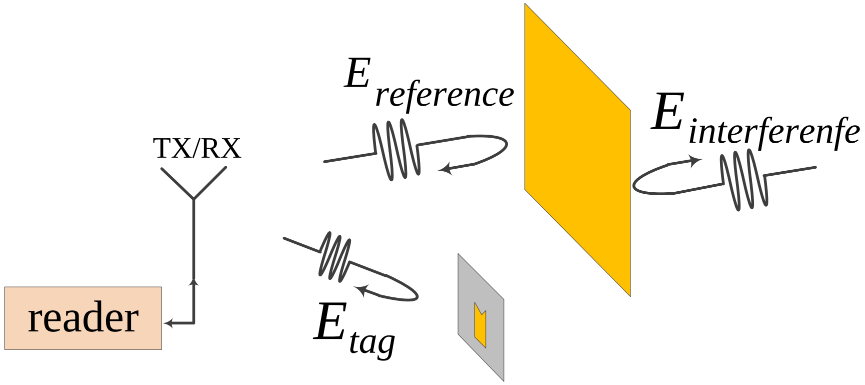
5. Conclusions

Conclusions

✓A relative distance calculation method based on interference is proposed.

$$d = \frac{c}{2(f_2 - f_1)}$$

✓A system unit for tag localization and decoding with high accuracy is proposed.


$E_{reference}$
$E_{interferenfe}$
TX/RX
reader
E_{tag}

References

- R. Miesen et al., “Where is the tag?,” *IEEE Microw. Mag.*, vol. 12, no. 7, pp. S49–S63, Dec. 2011.
- R.-E. A. Azim and N. C. Karmakar, “Chipless RFID tag localization,” *IEEE Trans. Microw. Theory Tech.*, vol. 61, no. 11, pp. 4008–4017, Nov. 2013.
- N. Zhang, M. Hu, L. Shao and J. Yang, “Localization of printed chipless RFID in 3-D space,” *IEEE Microw. Wireless Compon. Lett.*, vol. no. 5, pp. 373–375, May. 2016.
- R. Rezaiesarlak and M. Manteghi, “A space-frequency technique for chipless RFID tag localization,” *IEEE Trans. Microw.Theory Tech.*, vol.62, no. 11, pp. 5790–5797, Nov. 2014.
- N. C. Karmakar, “Tag, you're it radar cross section of chipless RFID tags,” *IEEE Microw. Mag.*, vol. 17, no.7, pp. 64–74, Jul. 2016.
- R. Rezaiesarlak, and M. Manteghi, “A space-time-frequency anticollision algorithm for identifying chipless RFID tags,” *IEEE Trans. Antennas Propag.*, vol. 62, no. 3, pp. 1425–1432, Mar. 2014.
- R. E. Azim, N. C. Karmakar and E. Amin, “Short Time Fourier Transform (STFT) for collision detection in chipless RFID systems,” in *Proc. Int. Symp. Antennas and Propag.* (ISAP), Hobart, Tasmania, Australia, pp. 1–4, Nov. 2015.